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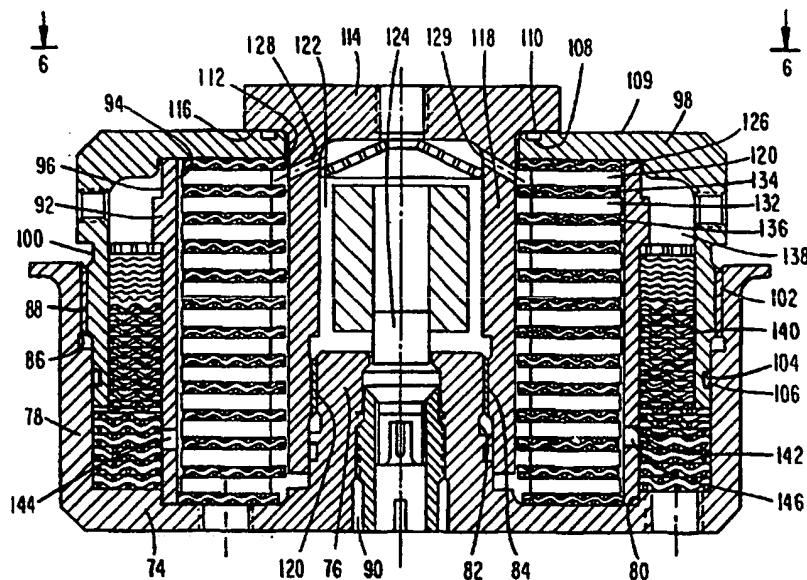
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(57) Abstract

A pyrotechnic composition having a fuel and an oxidizer, for directly inflating a vehicle crash bag, has an autoignition temperature below about 450 °F. The oxidizer, present in great excess compared to fuel, comprises alkali metal chlorate and/or perchlorate, any perchlorate comprising less than 92 % of total oxidizer. The fuel is a mixture of a thermally stable carbohydrate and from about 1-5 weight % of the total composition of an aliphatic polymeric polycarbonate. A device for inflating a vehicle crash bag has a central chamber (122); and ignitable squib (124) within the central chamber (122); a gas generating chamber (126) surrounding central chamber (122); a plurality of gas passages (128, 129) in fluid communication with central chamber (122) and with gas generating chamber (126); and a plurality of annular gas-generating preforms (130, 132) of any desired composition for generating crash-bag-filling amounts of gas. Preforms (130, 132) alternate with screens (134, 136) in gas generating chamber (126).

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INFLATING CRASH BAGS

Inflatable vehicle crash bags save lives. More and more consumers throughout the world are demanding that their new vehicles be equipped with these bags. Furthermore a number of jurisdictions are passing laws that require or encourage manufacturers to install these crash bags at least on the driver's side of the vehicle, but also sometimes on the passenger side as well.

While the literature is replete with failed attempts to provide reliable, safe crash bags, the trade has accepted two general types, namely the so called "all-pyro" type employing sodium azide type and the hybrid type utilizing pressurized argon.

Crash bags of the all-pyro type are equipped with a gas-generating composition of sodium azide (NaN_3) usually admixed with a heavy metal oxide, such as copper oxide (CuO). Upon ignition the composition produces hot nitrogen gas, condensed sodium oxide, and metallic copper at flame temperatures of about 1400°K . The crash bag is inflated by the hot nitrogen gas. Unfortunately sodium azide is highly toxic. Its toxicity requires special handling and manufacturing techniques in order to protect workers. Furthermore upon ignition, there is a great danger that the gaseous ignition products will carry some of the toxic sodium azide into the vehicle, poisoning the occupants. In an attempt to minimize or avoid this effect and to also avoid contact between the passenger and the sodium oxides, these crash bags are equipped with a porous metal filter. The intended

function of this filter is to remove condensed solid poisonous products such as sodium azide and sodium oxide. The smaller the filter mesh size, the smaller are the poisonous particles which are removed. However making the mesh too small inhibits passage of the gas. Every practical device is a compromise. These filters are not completely reliable in operation. They are, unfortunately, expensive to manufacture.

Some of the dangers of using sodium azide are minimized in devices of the hybrid type. These devices are described in a number of prior patents such as Scheffee U. S. Patents 3,723,205 and 4,981,534. Many of these devices employ a gas-generating composition of a polyvinyl chloride plastisol, an alkali metal perchlorate and lithium carbonate. This composition is available commercially from the Atlantic Research Corporation of Alexandria, Virginia, USA, under the tradename "ARCITE 479L". This composition ignites to produce combustion products which are discharged into a pressurized argon container. The container has a rupturable disc which ruptures in response to the increased pressure caused by mixing of the combustion products with argon thus producing an inflating mixture. This inflating mixture has an equilibrium temperature of about 1400°K. Unfortunately these devices suffer from a number of disadvantages. First is the possibility that the pressurized argon will leak from the cylinder. Even a very small leak will, over the course of the years of life of the typical vehicle, permit the argon pressure to drop below acceptable levels. If this happens there may not be enough gas to fill the crash bag. Alternatively, the gas produced by the resulting mixture may be so hot as to melt the bag or burn the passenger. Argon is difficult to detect by conventional means. In order to provide a means for testing for leaks, it has become common practice to mix the argon with a small percentage of helium. Helium is a very small molecule thus making leaks easier to detect. However the industrial process of mixing two inert gases is difficult to control and is difficult

to monitor. This can be accomplished only with expensive quality control techniques. The leaking helium, if any, is detected by means of an ionization gage held close to the argon container. Unfortunately commercially available ionization gages are expensive and are, therefore, not commonly found in the home or the typical automotive repair facility. The possible result is that the owner or operator of the vehicle is ignorant of the fact that argon has leaked from the crash bag, until a crash occurs.

A disadvantage common to both the sodium azide compositions and to the hybrid compositions is their high autoignition temperature (T_{ig}). This property and other significant safety properties are listed in Table I.

TABLE I

SAFETY PROPERTIES OF KNOWN COMPOSITIONS

Safety Property	$\text{NaN}_3 + \text{Fe}_2\text{O}_3$	$\text{NaN}_3 + \text{CuO}$	ARCITE
Autoignition ($^{\circ}\text{F}$)	741	767	896
Impact sensitivity	>300	145	200
Friction Sensitivity	600	900	1700
Electrical Discharge Sensitivity	6	6	6

The three prior art compositions listed in Table I all exhibit acceptable safety properties. This indicates that these compositions are relatively insensitive to accidental ignition in routine use.

Typically gas-generating compositions that are insensitive to ignition by friction, impact or other mechanical means are also insensitive to ignition by thermal means i. e. they have high autoignition temperatures. To the uninitiated, a high autoignition temperature might seem to be a desirable safety property, ensuring an extra margin of protection to the driver and occupants. However an equally important safety property is graceful failure of the gas generator when it is accidentally

exposed to fire. In this situation, the fire causes the gas-generating composition to release its gas when the composition reaches its autoignition temperature. However at temperatures above about 370°C (700°F), the steel combustion chamber and other parts of the crash bag device are weakened. Because of this weakening they can rupture with fragmentation creating the so called "hand grenade effect". For example at about 425°C (800°F) the yield strength of "4130 alloy steel" is only 68% of its room temperature value. While the dangers caused by the hand grenade effect can be minimized by design changes to the gas generator such as the use of heavier walls of the same steel or the use of different materials, the costs associated with such design changes are unacceptable to many automobile manufacturers.

Another option for avoiding the hand-grenade effect is the use of gas generating compositions having a low autoignition temperature. However it must be kept in mind that the autoignition temperature must be high enough to ensure safe storage at the highest normally encountered temperature.

The General Motors Corporation has decided that all crash bags must meet a vibration test described in MIL-STD-810D, Method 514.3, Figure 514.3-7. This test, hereinafter referred to as the "GM shake test", specifies that the gas generator must be shaken at certain prescribed frequencies for 40 hours. The gas generator is then fired and evaluated. Gas generators having friable compositions do not pass this test. All commercially successful gas generators must pass this test whether sold to General Motors or to others.

There is a long felt need in the art for a sodium-azide-free composition that can be ignited and sent directly to a crash bag without the use of pressurized argon. One such failed attempt is that described by Catanzarite US Patent 3,837,942. Catanzarite suggests the use of a number of toxic metal formates such as cupric formate (Col. 6, Line 56) and lead formate (Col. 7, Line 58). Catanzarite fails to solve the friability problem

by any means and fails to recognize the existence of polycarbonates, much less their use in such compositions.

Garner US 4,238,253 suggests the use of a composition containing calcium hydroxide. Unfortunately calcium hydroxide can be converted to lime (CaO) at the temperatures encountered during crash-bag inflation. Lime burns the skin and the eyes. Furthermore the Garner compositions have been found to have an autoignition temperature that is too high to avoid the hand grenade effect.

Many other compositions have been suggested but these are not suitable because they do not meet one or more of the following industry demanded criteria namely:

- (a) an autoignition temperature less than about 230°C (450°F); and
- (b) an impact sensitivity greater than 100 kg-cm; and
- (c) a friction sensitivity greater than 500 psi at a drop angle of 90°; and
- (d) an electrostatic discharge sensitivity greater than six Joules at five kilovolts; and
- (e) a flame temperature generally less than 1800°K and preferably less than 1400°K.

Accordingly it is an object of the present invention to provide an improved gas-generating composition and method for using such which is substantially free of one or more of the problems of the prior art.

Another object of the present invention to provide an improved gas-generator which is substantially free of one or more of the problems of the prior art.

An additional object of the present invention is to provide an improved gas-generating composition which has an autoignition temperature of less than 230°C (450°F).

Another object is to provide an improved gas-generating composition and method for using such which does not employ sodium azide.

Still another object is to provide an improved gas-generating composition and method for using such which produces combustion products which are free of heavy metals.

An additional object is to provide an improved gas-generating composition and method for using such which produces combustion products which are non-toxic.

Yet another object is to provide an improved gas-generating composition and method for using such which is easy to handle.

Yet another object is to provide an improved gas-generating composition and method for using such which does not require the use of expensive filters to filter the gaseous combustion products.

Yet another object is to provide an improved gas-generating composition and method for using such which permits the use of simple inexpensive filters for removal of non-toxic, particles.

Still another object is to provide an improved gas-generating composition and method for using such which does not employ pressurized argon.

Still another object is to provide an improved gas-generating composition and method for using such which does not employ pressurized helium.

Yet another object is to provide an improved gas-generating composition and method for using such which avoids the mixing of argon and helium.

Still another object is to provide an improved gas-generating composition which produces combustion products having a flame temperature below about 1800°K and preferably below about 1400°K.

Still another object is to provide an improved gas-generating composition and method for using such which produces combustion products which are non-toxic, oxygen-rich, and which is useful for directly inflating a vehicle crash bag without the

necessity of mixing the combustion products with any pressurized gas.

Additional objects and advantages of the present invention will be apparent to those skilled in the art by reference to the following detailed description and drawings wherein:

Figure 1 shows one physical form namely a pill of the compositions useful in the present invention; and

Figure 2 is a schematic representation of a crash bag device employing the compositions of the present invention; and

Figure 3 is a schematic representation of a test apparatus useful for evaluating the gas-generating compositions of the present invention and comparing them with other gas-generating compositions; and

Figure 4 is a graph showing the pressure generated upon ignition of a composition of the present invention with device pressure on the y-axis, test tank pressure on the y'-axis and time on the x-axis; and

Figure 5 is a sectional view of a gas-generating device of the present invention, taken along Line 5-5 of Figure 6; and

Figure 6 is a top view of a gas generating device of the present invention taken along Line 6-6 of Figure 5.

The above and other objects are accomplished according to the present invention, by providing a composition of matter, having autoignition temperature below about 230°C (450°F), which composition is particularly useful for directly inflating a vehicle crash bag. The composition of the present invention consists essentially of a certain oxidizer admixed with a certain fuel.

According to another aspect of the present invention there is provided a device for inflating a vehicle crash bag. The device has a central chamber; an ignitable squib within the central chamber; a gas-generating chamber surrounding the central chamber; a group of gas passages in fluid communication with the

central chamber and with the gas-generating chamber; and a number of annular gas-generating preforms for generating crash-bag-filling amounts of gas. The preforms alternate with annular screens in the gas-generating chamber. The device also has passages which provide a means for conveying the gas generated in the gas generating chamber to a crash bag.

The oxidizer can be any of the alkali metal chlorates, or the alkali metal perchlorates and mixtures thereof admixed.

The fuel consists essentially of (A) a thermally stable carbohydrate; and (B) an aliphatic polymeric polycarbonate.

In the composition of the present invention:

- (a) the oxidizer is present in a great stoichiometric excess compared to the fuel; and
- (b) any alkali metal perchlorate present in the composition comprises less than 92 weight percent of the oxidizer, based on the total weight of oxidizer present; and
- (c) the polymeric polycarbonate comprises from about one weight percent to about five weight percent of the composition based on the total weight of the composition.

Examples of suitable alkali metal chlorates include sodium chlorate, potassium chlorate and lithium chlorate. Examples of suitable alkali metal perchlorates include sodium perchlorate, potassium perchlorate and lithium perchlorate. A preferred oxidizer is sodium chlorate. The most preferred oxidizer is potassium chlorate (KClO_3) because of cost, availability and reactivity.

Thermally stable carbohydrates are those carbohydrates which when formed into cylindrical pills having a diameter of 1.25 mm (1/2 inch) and a height of 0.62 mm (1/4 inch) after storage for 30 days in air at 107°C (225°F):

- (a) exhibit a weight loss of less than one percent; and
 - (b) exhibit a change in diameter of less than one percent;
- and
- (c) exhibit a change in height of less than one percent; and

(d) exhibit no color change to the unaided eye when viewed in white light.

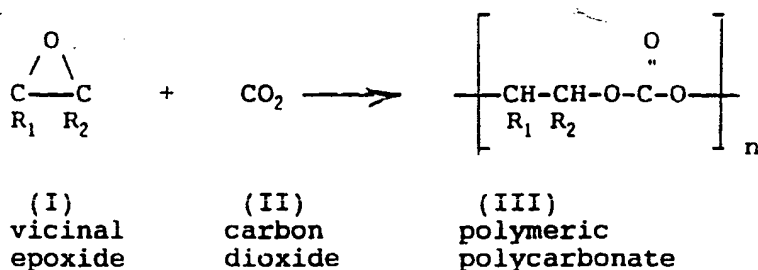
Examples of thermally stable carbohydrates useful in the present invention include among others corn starch, wheat starch, cellulose, dextrin, alpha-lactose, beta-lactose, ascorbic acid, benzoic acid, maltose, maltose monohydrate, mannoheptose, and mannoheptose monohydrate.

Glucose, fructose and sucrose are not thermally stable carbohydrates and are not useful in the compositions of the present invention.

The preferred thermally stable carbohydrate is beta-lactose having the empirical formula, $C_{12}H_{22}O_{11}$. It is preferred because of cost, availability and reactivity. Water of hydration is preferably absent in the beta-lactose of the present invention.

A wide variety of polymeric polycarbonates are useful in the present invention. The preferred polymeric polycarbonates are those wherein the carbonate linkages are in the backbone of the polymer.

The most preferred polymeric polycarbonates are produced by reacting a vicinal organic epoxide of Formula I with carbon dioxide of Formula II, to produce a polymeric polycarbonate of Formula III:



In the above reaction, R_1 and R_2 are independently selected from the group consisting of hydrogen and monovalent organic radicals. The monovalent organic radicals can be aromatic, aliphatic, or

mixed. Aliphatic are preferred. Suitable aliphatic radicals, include methyl, ethyl, propyl, isopropyl, butyl, isobutyl, t-butyl, and octyl. The most preferred class of polymeric polycarbonates are poly(alkylene carbonates) examples of which include poly(ethylene carbonate) and poly(propylene carbonate), which is greatly preferred because of cost, availability and reactivity. The quantity "n" is from about 10 to about 10,000 and is preferably from about 50 to about 5,000.

An amount of polymeric polycarbonate sufficient to improve the strength of the composition is employed. In general the weight ratio of thermally stable carbohydrate to polymeric polycarbonate is from about 10:1 to about 1:10 and preferably is from about 10:2 to about 2:10.

It is absolutely necessary to the practice of the present invention that the oxidizer be present in a great stoichiometric excess when compared to the fuel. In this manner, all hydrogen is converted to water and substantially all carbon is converted to carbon dioxide. In this manner the undesirable production of toxic carbon monoxide is avoided. Another advantage of the use of a great stoichiometric excess of oxidizer is that the resultant gases are oxygen-rich and can be breathed by the driver and passengers. In general a great stoichiometric excess is present when the weight ratio of oxidizer to fuel is from about 4:1 to about 25:1 and preferably from about 6:1 to about 16:1. As the ratios get much lower the flame temperature tends to undesirably increase and the amount of carbon monoxide tends to undesirable increase. As the ratios get much higher, the flame temperature may reach a point at which it is too low for bag inflation. Furthermore the burn rate may decrease with the result that bag inflation may not occur within the desired time.

The compositions of the present invention can contain minor amounts of other ingredients that do not materially affect the characteristics of the composition, but the compositions of

the present invention preferably consist essentially of the recited ingredients. Examples of additional ingredients include opacifiers such as carbon black employed to inhibit the uneven burning phenomenon called worm-holing.

Referring now to Figure 1 there is shown a pill 10 which represents one form in which the compositions of the present invention can be used in a crash bag device 20. The cylindrical pill 10 has a diameter ("d") of 1.25 mm (1/2 inch) and a height ("h") of 0.62 mm (1/4 inch).

Figure 2 shows that the device 20 has a steel container 22 holding the pills such as the pill 10. The container 22 is equipped with an electric squib 24 in series with a crash-responsive switch 26. The container 22 has an outlet (not shown) which discharges directly into a crash bag 28. In operation the switch 26 closes in response to a crash or other sudden deceleration of the vehicle (not shown) permitting current to flow in the circuit igniting the squib 24. The ignited squib 24 ignites the composition of the present invention in the form of the pills such as the pill 10. The burning of the composition of the present invention produces a gaseous mixture. In accordance with the present invention, this gaseous mixture has a temperature generally less than about 1800°K and preferably less than about 1400°K. It is non-toxic and is oxygen-rich. This gaseous mixture travels directly into the bag 28 and inflates it. The gaseous mixture is cooled by expansion and by contact with the bag 28. In accordance with the present invention, it has been found that this gaseous mixture does not melt the nylon of the bag 28.

Referring now to Figure 3 there is shown a test apparatus 60 useful for testing the compositions and devices of the present invention. The apparatus 60 comprises a tank 62 having a pressure gage 64, a thermometer 66 and a flange 68. A sample chamber 70 having a flange 72 can be connected to the flange 68 of the tank 62. A device or composition to be tested

is placed in the chamber 70 which is then attached to the tank 62 by bolting together the flanges 68, 62. The temperature of the thermometer 66 is noted, and the switch 26 is closed. The pressure is recorded by the gage 64 or by a recording pressure meter (not shown).

Referring now to Figures 5 and 6, there is shown a device 73 for inflating a vehicle crash bag. The device 73 has a base 74 which has a central cylindrical boss 76; a cylindrical outer wall 78; and a cylindrical shoulder 80 intermediate between the boss 76 and the outer wall 78. The outer surface 82 of the boss 76 has external threads 84. The inner surface 86 of the outer wall 78 has threads 88. The boss 76 has an axial squib-receiving hole 90.

The device 73 also has a sleeve 92 which has a cylindrical inner surface 94 and a cylindrical outer surface 96 parallel to the cylindrical inner surface 94. The cylindrical outer surface 96 fits against the shoulder 80 of the base 74.

The device 73 carries a cylindrical cap 98 which has an outer wall having external threads of the same diameter and pitch as the inner threads of the outer wall 78 of the base 74. These threads are adapted to mate with each other. The cap 98 has a first O-ring-receiving slot 104 in the outer wall 78. There is an O-ring 106 in the first slot 104. The O-ring 106 seals the outer wall 78 of the cap 98 to the inner surface 86 of the outer wall 78 of the base 74. A second O-ring-receiving slot 108 is in the upper surface 109 of the cap 98. An O-ring 110 is in the second slot 108. There is a cylindrical central chamber 122 in the cap 98.

The device 73 further comprises a T-shaped plug 114 having a planar lower surface 116 and a cylindrical extension 118. There are internal threads 120 on the inside of the cylindrical extension 118. These threads 120 have the same diameter and pitch as the external threads 84 on the boss 76 and are therefore adapted to mate with it.

It is readily apparent that the space between the boss 76 and the plug 114 defines a central chamber 122. An ignitable squib 124 is located within the central chamber 122. There is also an annular space between the outer surface of the extension 118 of the plug 114 and the inner wall 94 of the sleeve 92 which defines a gas-generating chamber 126 surrounding the central chamber 122.

The device 73 is provided with a plurality of gas passages 128, 129 within the plug 114 near its top which gas passages 128, 129 are in fluid communication with the central chamber 122 and with the gas-generating chamber 126.

The device 73 holds a plurality of annular gas-generating preforms 130, 132. The preforms are for generating crash-bag-filling amounts of gas. The preforms 130, 132 alternate with a plurality of annular screens 134, 136 in the gas-generating chamber 126.

The outside surface 94 of the sleeve 92 and the inside surface 86 of the outer wall 78 of the base 74 define an outer chamber 138. There are a plurality of screens 140, 142 in this outer chamber 138. A plurality of gas passages 144, 146 connect the gas-generating chamber 126 to the outer chamber 138. Gas passages 152, 156 provide a means for conveying gas from the top of the outer chamber 138 to a crash bag.

The device 73 is provided with test ports 148, 150, 154. During laboratory tests, pressure sensors can be placed in these ports to measure pressure as a function of time. The ports 148, 150, 154 were employed to produce Figure 4. Commercial devices need not have these ports.

The device 73 can optionally have an accelerator 158, which is a gas generating composition which produces hot gas to ignite the preforms 130, 132. A wide variety of compositions can be used as the accelerator 156, however the preferred composition is that sold by the Atlantic Research Company of Alexandria, Virginia, USA, under the tradename "ARCITE 479L". This

composition is described in Example 1 appearing in Column 4 at Lines 1 through 30 of Scheffee U. S. Patent 4,981,534.

The invention may be better understood by reference to the following examples wherein all parts and percentages are by weight unless otherwise indicated. These examples are designed to teach those skilled in the art how to practice the present invention and represent the best mode presently known for practicing the invention.

In these examples the following terms have the following meanings.

"Impact" means the impact in kg-cm necessary to ignite measured according to the well known US Bureau of Mines standard.

"Friction" means the well known friction test promulgated by the Allegheny Ballistics Laboratory (ABL) in psi measured at a drop angle of 90°.

"Electrical discharge sensitivity" means that electrostatic discharge required to ignite measured in Joules at five kilovolts.

"Autoignition" is that temperature in °F when the sample is placed on a copper block and heated in an oven. The second number given is the autoignition temperature determined by a Differential Scanning Calorimeter.

Example 1

This example illustrates the synthesis of a preferred gas-generating composition of the present invention.

The following quantities of the following ingredients were combined as indicated.

<u>Item</u>	<u>Ingredient</u>	<u>Quantity in parts by weight</u>
A	KClO ₃	93.0
B	beta-lactose	2.0
C	polycarbonate	4.9
D	carbon-black	0.1
	subtotal	100.0
E	acetone	20.0

The polycarbonate is poly(propylene carbonate) having a number average molecular weight of 50,000 measured by gas phase chromatography, a density of 1.26 measured by ASTM D-792, a tensile strength of about 5500 psi at 23°C, a glass transition temperature of 40°C, and a heat of combustion of 8000 BTU/lb. It is sold by the Air Products Company of Allentown, Pennsylvania, USA under the tradename "PC".

Items A through E are mixed to form a dough-like slurry. This dough-like slurry is heated to 50°C whereupon most of the acetone evaporates leaving a crumbly mixture. This crumbly mixture is forced through a screen of ten mesh per inch to produce uniform crumbs. These uniform crumbs are formed into pills such as the pill 10 of Figure 1 having a diameter, "d", of 12.5mm (1/2 inch) and a height, "h" of 2.5mm (0.10 inches).

Examples 2 through 6

These examples are illustrative of additional compositions of the present invention with increasing amounts of polycarbonate and decreasing amounts of beta-lactose.

The procedure of Example 1 was repeated employing the same procedures, ingredients, times and conditions except that the quantities of ingredients were replaced by those shown in Table II.

		<u>TABLE II</u>				
		Example Number				
		2	3	4	5	6
<u>Item</u>	<u>Ingredient</u>	(pts)	(pts)	(pts)	(pts)	(pts)
A	KClO ₃	93	93	93	93	93
B	beta-lactose	6	5	4	3	2
C	polycarbonate	1	2	3	4	5
D	carbon black	0.1	0.1	0.1	0.1	0.1
	Autoignition (°F)	410	411	409	410	369

All compositions exhibit thermal stability and pass the GM shake test.

Example 7

This comparative example is not illustrative of the present invention. This non-inventive example shows the undesirable results obtained when the polycarbonate is omitted.

The procedure of Example 2 was repeated employing the same procedures, ingredients, times and conditions except that the polycarbonate was omitted and the quantity of beta lactose was increased from 6 parts to 7 parts. The composition does not pass the GM shake test.

Example 8

This example is not illustrative of the present invention, but is presented here for comparative purposes. This example gives the results of the calcium hydroxide containing composition of Example I of Garner U. S. Patent 4,238,253.

A composition consisting of 0.5 weight percent carbon black, 2 weight percent polyvinyl acetate, 7 weight percent corn starch, 48.5 weight percent sodium chlorate and 42 weight percent calcium hydroxide was intimately mixed under methylene chloride, dried, and pressed into pellets.

The autoignition temperature was twice measured and found to be 531°F and 534°F giving an average of about 532°F. This undesirably high autoignition temperature renders this Garner Composition completely unsuitable for use as a gas generating composition for crash bag inflation.

Example 9

This example is illustrative of the present invention. It shows the desirable results obtained when the polyvinyl acetate of Garner is replaced with polycarbonate and the calcium hydroxide of Garner is replaced with sodium chlorate.

The procedure of Example 2 was repeated with two and only two exceptions. The polyvinyl acetate was replaced by an equal weight of polycarbonate and the calcium hydroxide was replaced by an equal weight of sodium chlorate.

The autoignition temperature was twice measured and found to be 435°F and 438°F giving an average of about 437°F. This desirably low autoignition temperature renders this inventive composition eminently suitable for use as a gas generating composition in accordance with this invention.

Example 10

The gas generation profile of the inventive composition of Example 1 was measured and the results recorded in Figure 4. In that figure the curve 42 shows the maximum allowable test tank pressure, the curve 44 shows the minimum allowable test tank pressure and the curve 46 shows the experimentally determined test tank pressure of the inventive composition of Example 1. The actual values can be read from the y-axis. By reference to these curves it can be seen that the inventive composition is within the required design parameters with respect to test tank pressure generation.

The curve 48 shows the pressure within the device 73 measured at port 148, recorded on the y-axis. Curve 49 the pressure within the device 73 measured at port 150, recorded on the y-axis.

Example 11

This example is designed to teach those skilled in the art how to produce a composition of the present invention wherein some of the KClO_3 is replaced with KClO_4 .

The procedure of Example 1 was repeated employing the same procedures, ingredients, times and conditions except that four parts by weight of the KClO_3 was replaced with an equal weight of KClO_4 with similar results.

Examples 12-17

These examples are designed to teach those skilled in the art how to practice the invention with various carbohydrates.

The procedure of Example 1 was repeated employing the same procedures, ingredients, times and conditions except that the beta-lactose was replaced with an equal weight of the other

carbohydrates shown in Table III with similar results.

TABLE III

Example No.	Carbohydrate
12	sucrose
13	wheat flour
14	corn starch
15	fructose
16	microcrystalline cellulose
17	guar gum

Although the invention has been described in detail with reference to certain preferred embodiments thereof; it will be understood that variations can be made without departing from the spirit of the invention as described above and without departing from the scope of the claims as given below.

What is claimed is:

1. A composition of matter for directly inflating a vehicle crash bag, consisting essentially of:

I. an oxidizer selected from the group consisting of alkali metal chlorates, alkali metal perchlorates and mixtures thereof; admixed with

II. a fuel consisting essentially of:

A. a thermally stable carbohydrate; and

B. an aliphatic polymeric polycarbonate; and

with the provisos that:

(a) the oxidizer is present in a great stoichiometric excess compared to the fuel; and

(b) any alkali metal perchlorate present in the composition comprises less than 92 weight percent of the oxidizer, based on the total weight of oxidizer present; and

(c) the polymeric polycarbonate comprises from about one weight percent to about five weight percent of the composition based on the total weight of the composition; and

(d) the composition has an autoignition temperature below about 450°F.

2. The composition of Claim 1 wherein the thermally stable carbohydrate is β -lactose.

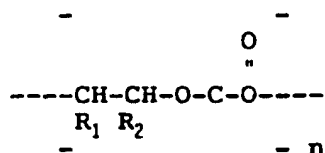
3. The composition of Claim 2 wherein the β -lactose is free of water of hydration.

4. The composition of Claim 1 wherein the thermally stable carbohydrate is α -lactose.

5. The composition of Claim 1 wherein the thermally stable carbohydrate is wheat flour.

6. The composition of Claim 1 wherein the thermally stable carbohydrate is corn starch.

7. The composition of Claim 1 wherein the polymeric polycarbonate has the formula:



wherein R_1 and R_2 are independently selected from the group consisting of hydrogen and monovalent organic radicals; and wherein "n" is a number from about 10 to about 10,000.

8. The composition of Claim 1 wherein the polymeric polycarbonate is a poly(alkylene carbonate).

9. The composition of Claim 1 wherein the polymeric polycarbonate is poly(propylene carbonate).

10. The composition of Claim 1 wherein the aliphatic polymeric polycarbonate is poly(ethylene carbonate).

11. The composition of Claim 1 wherein the weight ratio of oxidizer to fuel is from about 3:1 to about 20:1.

12. The composition of Claim 2 wherein the weight ratio of β -lactose to aliphatic polymeric polycarbonate is from about 10:1 to about 1:10.

13. The composition of Claim 1 wherein the alkali metal chlorate is a mixture of potassium chlorate and potassium perchlorate in a weight ratio of about 1:8 to about 100:1.

14. The composition of Claim 1 which is black in color.

15. The composition of Claim 1 which is black in color by virtue of the inclusion therein of worm-hole-eliminating amounts of carbon black.

16. The composition of Claim 1 wherein the components thereof chemically combine with one another to produce a gas having a temperature less than about 1800°K.

17. The composition of Claim 16 wherein the gas is non-toxic.

18. The composition of Claim 16 wherein the gas is substantially free of fly-ash.

19. A composition of matter for directly inflating a vehicle crash bag, consisting essentially of:

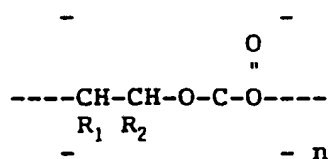
I. an oxidizer of potassium chlorate admixed with

II. a fuel consisting essentially of:

A. β -lactose; and

B. an aliphatic polymeric polycarbonate of the

formula:



wherein R_1 and R_2 are independently selected from the group consisting of hydrogen, methyl, and ethyl; and

wherein "n" is a number from about 10 to about 10,000; with the provisos that:

(a) the weight ratio of oxidizer to fuel is from about 3:1

to about 20:1; and

(b) the polymeric polycarbonate comprises from about one weight percent to about five weight percent of the composition based on the total weight of the composition; and

(c) the composition has an autoignition temperature below about 450°F.

20. A device for inflating a vehicle crash bag comprising:

- A. a central chamber; and
- B. an ignitable squib within the central chamber; and
- C. a gas-generating chamber surrounding the central chamber; and
- D. a plurality of gas passages in fluid communication with the central chamber and with the gas-generating chamber; and
- E. a plurality of annular gas-generating preforms for generating crash-bag-filling amounts of gas; said preforms alternating with a plurality of annular screens in the gas-generating chamber; and
- F. means for conveying the gas generated in the gas generating chamber to a crash bag.

21. A device for inflating a vehicle crash bag comprising:

- A. a central chamber; and
- B. an ignitable squib within the central chamber; and
- C. a gas-generating chamber surrounding the central chamber; and
- D. a plurality of gas passages in fluid communication with the central chamber and with the gas-generating chamber; and
- E. a plurality of annular gas-generating preforms for generating crash-bag-filling amounts of gas; said preforms alternating with a plurality of annular screens in the gas-generating chamber; and

- F. an outer chamber; and
- G. a plurality of screens in the outer chamber; and
- H. a plurality of gas passages connecting the gas-generating chamber to the outer chamber; and
- F. means for conveying gas from the top of the outer chamber to a crash bag.

22. A device for inflating a vehicle crash bag comprising:

- A. a base having a central cylindrical boss; a cylindrical outer wall; and a cylindrical shoulder intermediate between the boss and the outer wall;
 - wherein the outer surface of the boss has external threads;
 - and
 - wherein the inner surface of the outer wall has threads; and
 - wherein the boss has an axial squib-receiving hole; and
- B. a sleeve having a cylindrical inner surface and a cylindrical outer surface parallel to the cylindrical inner surface; wherein the cylindrical outer surface fits against the shoulder of the base; and
- C. a cylindrical cap having an outer wall having external threads of the same diameter and pitch as the inner threads of the outer wall of the base and adapted to mate thereto; a first O-ring-receiving slot in the outer wall of the cap; an O-ring in the first slot; wherein the O-ring seals the outer wall of the cap to the inner surface of the outer wall of the base; a second O-ring-receiving slot in the upper surface of the cap; an O-ring in the second slot; a cylindrical central chamber in the cap; and
- D. a T-shaped plug having a planar lower surface and a cylindrical extension; internal threads on the inside of the cylindrical extension of the same diameter and pitch as the external threads on the boss and adapted to mate thereto;

- E. wherein the space between the boss and the plug defines a central chamber; and
- F. an ignitable squib within the central chamber; and
- G. wherein the annular space between the outer wall of the plug and the inner wall of the sleeve defines a gas-generating chamber surrounding the central chamber; and
- H. a plurality of gas passages within the plug near its top which gas passages are in fluid communication with the central chamber and with the gas-generating chamber; and
- I. a plurality of annular gas-generating preforms for generating crash-bag-filling amounts of gas; said preforms alternating with a plurality of annular screens in the gas-generating chamber; and
- J. wherein the outside surface of the sleeve and the inside surface of the outer wall of the base define an outer chamber; and
- K. a plurality of screens in the outer chamber; and
- L. a plurality of gas passages connecting the gas-generating chamber to the outer chamber; and
- M. means for conveying gas from the top of the outer chamber to a crash bag.

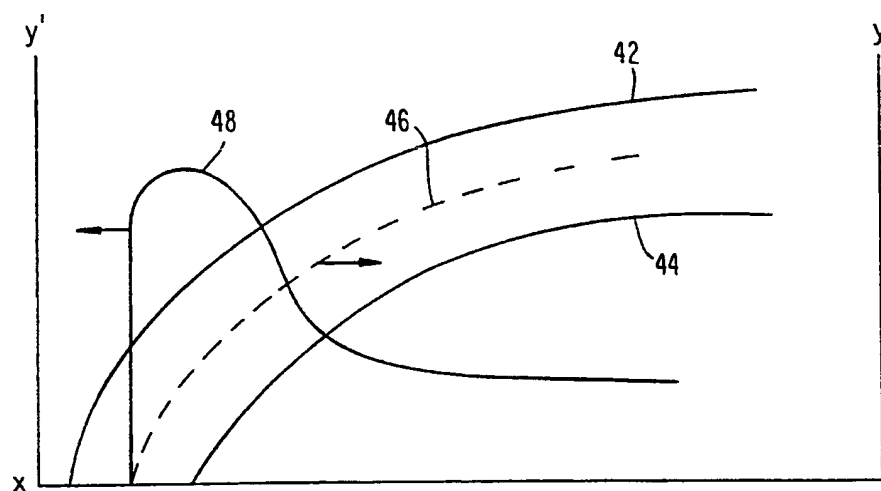
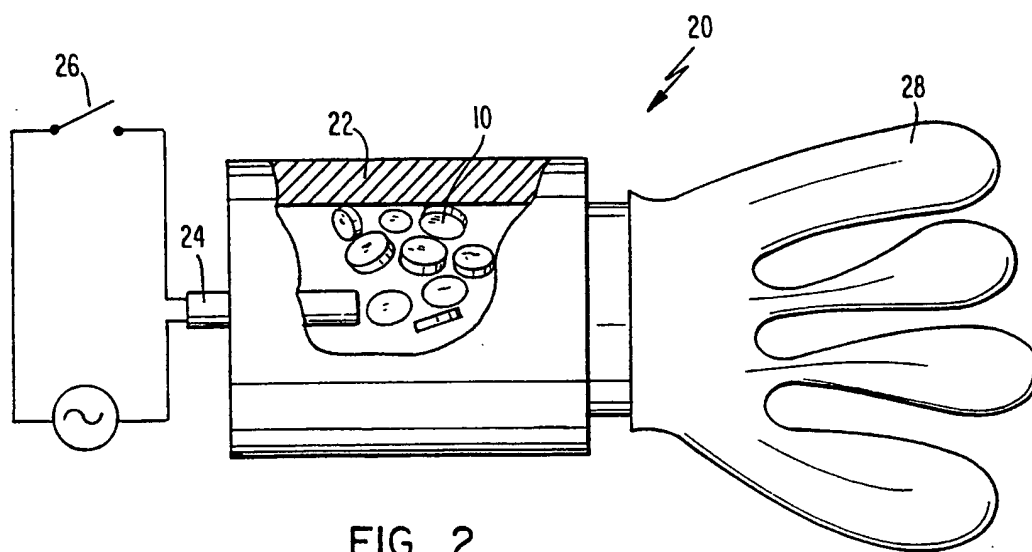
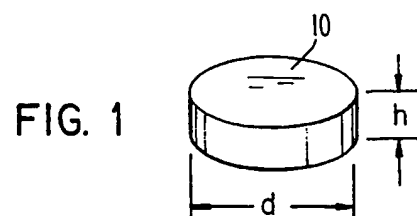


FIG. 3

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SUBSTITUTE SHEET

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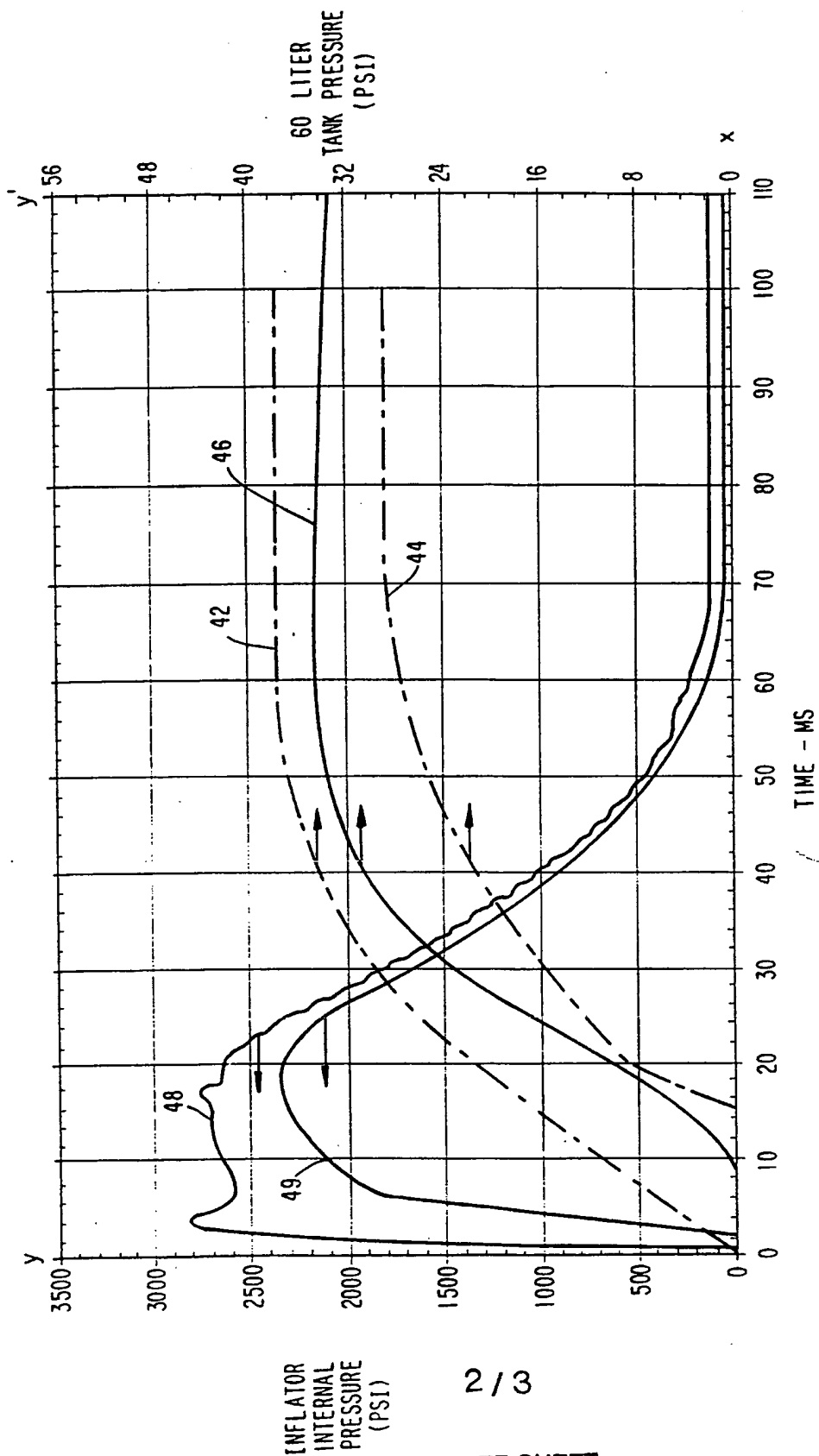


FIG. 4

FIG. 5

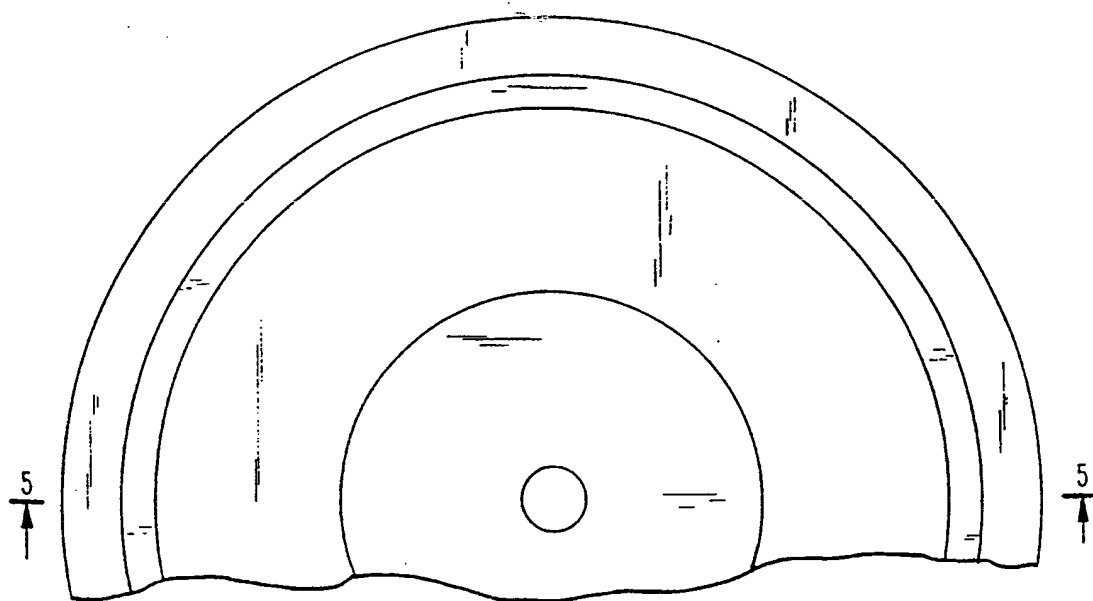
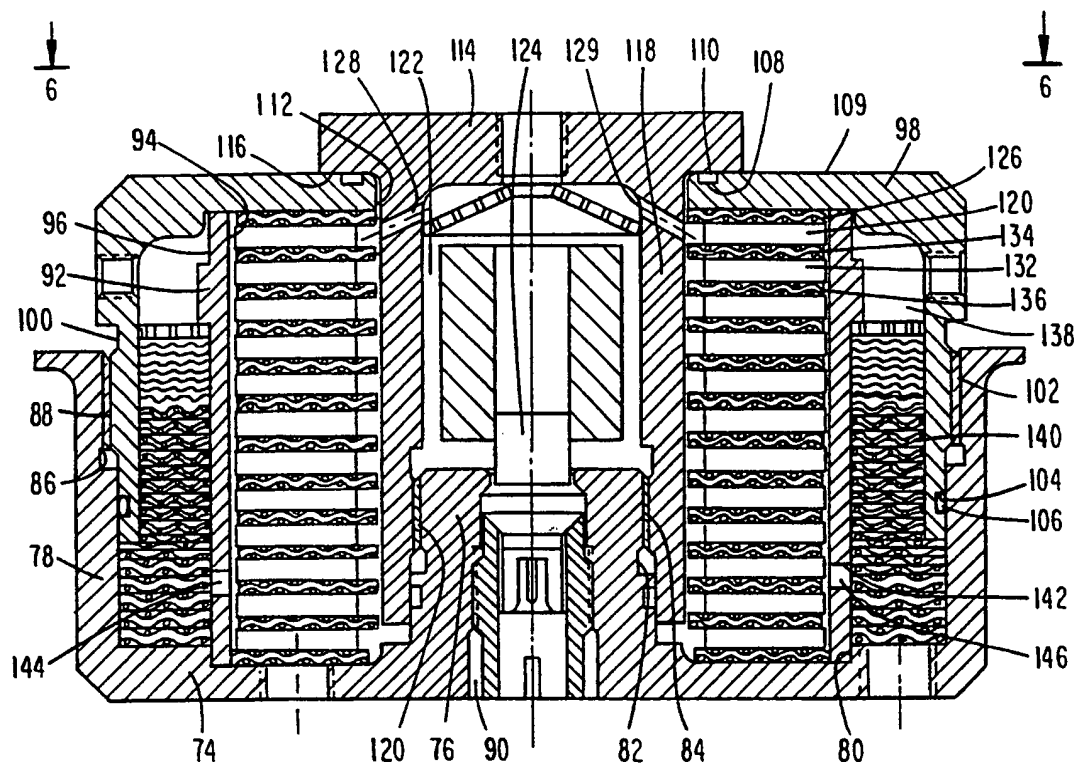


FIG. 6
SUBSTITUTE SHEET

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/07998

A. CLASSIFICATION OF SUBJECT MATTER IPC(5) :B6OR 21/28; CO6B 45/10. US CL :280/741; 149/19.5 According to International Patent Classification (IPC) or to both national classification and IPC														
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 280/741; 149/19.5 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) USPAT; Inflat ##### Perchlorate, 149/Class, Carbohydrate, (Propylene or Polypropylene) (w) Carbonate.														
C. DOCUMENTS CONSIDERED TO BE RELEVANT														
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.												
Y	US,A, 3,986,908 (Grebert et al.) 19 October 1976. See the Abstract.	1-19												
Y	US,A, 4,214,438 (Hamilton et al.) 29 July 1980. See col. 2, lines 26-27.	1-19												
Y	US,A, 4,309,229 (Hamilton et al.) 05 January 1982. See col. 2, lines 22-43.	1-19												
Y	US,A, 4,931,112 (Wardle et al.) 05 June 1990. See col. 2, lines 54-68	1-19												
Y	US,A, 5,015,309 (Wardle et al.) 14 May 1991. See col. 4, lines 24-38	1-19												
Y	US,A, 3,862,866 (Timmerman et al.) 28 January 1975. See col. 7, lines 16-23 & col. 5, lines 5-10 and 56-66.	1-19												
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.														
<table border="0"> <tr> <td>* Special categories of cited documents:</td> <td>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>"A" document defining the general state of the art which is not considered to be part of particular relevance</td> <td>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>"E" earlier document published on or after the international filing date</td> <td>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>"&" document member of the same patent family</td> </tr> <tr> <td>"O" document referring to an oral disclosure, use, exhibition or other means</td> <td></td> </tr> <tr> <td>"P" document published prior to the international filing date but later than the priority date claimed</td> <td></td> </tr> </table>			* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"A" document defining the general state of the art which is not considered to be part of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family	"O" document referring to an oral disclosure, use, exhibition or other means		"P" document published prior to the international filing date but later than the priority date claimed	
* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention													
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone													
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art													
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family													
"O" document referring to an oral disclosure, use, exhibition or other means														
"P" document published prior to the international filing date but later than the priority date claimed														
Date of the actual completion of the international search 20 DECEMBER 1993		Date of mailing of the international search report 09 FEB 1994												
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231		Authorized officer EDWARD A. MILLER												
Facsimile No. NOT APPLICABLE		Telephone No. (703) 308-3267												

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/07998

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,238,253 (Garner) 09 December 1980. See the Abstract & col. 2, lines 39-56	1-19
Y	JP, A, 1-293,112 (NGK) 27 November 1989. See the Abstract	20-22
Y	US,A, 5,062,367 (Hayashi et al.) 05 November 1991. See the Abstract of Fig. 1 & 13.	20-22
Y	US,A, 4,890,860 (Schneider) 02 January 1990. See the Abstract and Fig. 1	20-22
Y	US,E, RE 30,327 (Damon) 08 July 1980. See Fig. 1.	20-22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/07998

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Group I, claims 1-19, drawn to a composition classified in class 149, subclass 19.5
Group II, claims 20-22, drawn to apparatus, classified in class 280, subclass 741

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.